THE COST EFFECTIVENESS OF FIRE STATION SITING
&
THE IMPACT ON EMERGENCY RESPONSE

EXECUTIVE DEVELOPMENT

BY: Jim Johnston
        Moraga-Orinda Fire Protection District
        Orinda, California

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ABSTRACT

This research project analyzed the factors that influence the decision making process for the siting of fire stations in relation to emergency response. The problem was that taxpayer dollars were not being cost effectively utilized. The purpose of this applied research paper was to determine whether it was feasible for the Moraga-Orinda Fire District to maximize community emergency response and cost effectiveness by relocating and combining Fire Station 43 and Fire Station 16.

The research employed was both historical and action. The research was historical through the literature review to the extent of understanding the relationship between fire station location and emergency fire response.

The research was action research in that the information gathered was applied in a real-world context.

The research questions to be answered were:

1. What are the criteria to be taken under consideration when determining a site to construct a fire station?

2. What would the impact of relocating and consolidating Fire Station 43 and Fire Station 16 have on the response of emergency services?

3. What are other factors that need to be considered in moving forward with an implementation plan to combine fire stations?

The principal procedure utilized a computer-modeling program to determine response times and distances for existing and proposed fire station locations. The data collected from various studies was used to compare service impact with various station configurations.

The results indicated that combining two existing fire stations and relocating to one strategic site resulted in improved emergency coverage with a savings of $520,000 per year in operational costs and $1,000,000 in capital costs.

It was recommended to proceed with the construction of a single fire station to replace two existing fire stations provided that organizational and community concerns were addressed.

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INTRODUCTION

The problem is that taxpayer dollars are not being cost effectively utilized. The Moraga-Orinda Fire District owns and occupies a fire station (Fire Station 43) proximate to a fire station owned and occupied by an adjoining jurisdiction (Contra Costa County Fire Station 16). Both of these fire stations have been identified as having extensive structural and functional problems necessitating replacement.

The purpose of this applied research paper is to determine whether it is feasible for the Moraga-Orinda Fire District to maximize community emergency response and cost effectiveness by relocating and combining Fire Station 43 and Fire Station 16.

In this study the action research methodology is being utilized to address this problem.

The research questions to be answered are:

4. What are the criteria to be taken under consideration when determining a site to construct a fire station?

5. What would the impact of relocating and consolidating Fire Station 43 and Fire Station 16 have on the response of emergency services?

6. What are other factors that need to be considered in moving forward with an implementation plan to combine fire stations?

BACKGROUND AND SIGNIFICANCE

The Moraga-Orinda Fire District (MOFD) was formed on July 1, 1997 when over 80% of the voters of Moraga and Orinda established a single comprehensive Fire District. A five-member Board elected by the residents governs the Fire District. The Fire District provides services for all emergencies including residential and commercial fires, medical

emergencies, wildland fires and other hazardous conditions. The service area is approximately 63 square miles, and has a population of 34,000.

The MOFD has five fire stations with a current staff of 65.5 employees and an operating budget of $8.9 million. Five engine companies and two ambulances, all equipped to provide advanced life support (ALS), respond to approximately 2,100 emergency calls per year.

Directly east of the MOFD boundary lies the city of Lafayette, that is serviced by the Contra Costa County Fire Protection District (Con Fire). Three fire stations are located in the city, two that are proximate to the MOFD and respond as part of an automatic aid agreement.

When the five fire stations in the MOFD and three fire stations located in the City of Lafayette are plotted on a map they appear equidistant from one another, with one exception. That one exception is the distance between Fire Station 43 in the MOFD and Fire Station 16 in Con Fire that appear significantly closer in relation to the other fire stations. Actual road driving confirms this observation. Fire Station 43 and Fire Station 16 are 1.6 miles apart. Other fire stations in Lafayette and the MOFD are approximately 3 miles apart.

Further comparison shows that Fire Station 43 and Fire Station 16 each has a single engine company staffed by a minimum of three firefighters per 24-hour shift. The emergency call volume is similar with each of the stations responding to an average of 15 to 18 calls per month. (Statistical data was obtained through Contra Costa County Fire Protection District). Combining these two stations would result in 30 to 36 emergency calls per month, or less than one emergency call per day.

Personnel costs to staff a three-person engine company are approximately $1,000,000 per year. This includes base salaries, workers compensation and health insurance costs and employer contributions for the retirement system. Fire station maintenance and utility costs are approximately $20,000 per year. Apparatus fuel and maintenance costs are approximately $15,000 per year. Recent estimates for fire station construction (not including land purchase) are $1,900,000 for a single engine fire station. The estimated cost for a new fire engine is $375,000. (MOFD adopted 1999/2000 fiscal budget).

The determination that both Fire Station 43 and Fire Station 16 are in need of replacement makes this a timely research study. Fire Station 16 has been vacated for approximately seven years due to structural defects. Firefighters are currently housed in a modular building directly adjacent to the existing structure. Station 43 is not adequately constructed to withstand a major earthquake and is considered sub-standard from a functional standpoint (Loving & Campos, 1998).

If one fire station could effectively serve the emergency response needs that two fire stations currently serve, a substantial shared savings could be realized by the MOFD and Con Fire; approximately $520,000 each per year in operating costs and $1,000,000 each in capital costs for a newly constructed fire station. If the extra engine that resulted from combining the fire stations could be re-deployed to another needed area, potential savings could be achieved there as well.

Because of these observations and the potential cost savings the subject of objective fire station location criteria is worth exploring. Providing a service level to the

community that is equal to or better than the existing condition and at a lower cost could have a significant impact utilizing taxpayer dollars effectively.

Through the utilization of this research paper, we will identify the impact of a station merger and relocation on the delivery of services. The application of problem solving analysis, development of a model to evaluate research, and creating organizational change are areas addressed in the Executive Fire Officer Program at the National Fire Academy relevant to this research project.

LITERATURE REVIEW

The analysis of fire station location has as its roots in the utilitarian principle of the greatest good for the greatest number of people. Add the factor of speed, and you have the fundamental equation for determining the proper siting of fire stations within a community. In other words how can communities strategically locate fire stations so that they can serve the most people in the fastest way possible (Springer, 1995)?

There are many approaches to this issue. William Gay and Alan Siegel (1987) suggest relevant criteria should include distance between stations, population densities and special hazards when attempting to determine the location and number of fire stations in a community. They recommend a comprehensive planning approach that reviews the entire operation of a fire department in order to provide "…the most cost effective system of fire protection a possible" (1987, p.1). Included in that analysis is National Standards, community fiscal capacity and fire service delivery costs, fire incident location and response time analysis, and total fire protection planning of which fire prevention is a key component (Gay & Siegel, 1987).

Gary B. McCarraher (1992) states that there are few standards regarding number and placement of fire stations. Historically they have been based on standards set forth by the Insurance Services Office (ISO). Site selections should consider positive factors such as proximity to major intersections and major crossings like railways, rivers and freeways. Areas to avoid include flood prone areas, natural barriers (mountains and valleys), and one-way streets or bottlenecks.

Springer (1995) utilizes absolute and relative measures that provide a "standard of care" that is quantifiable and measurable. Absolute measures historically look at the total number of emergency occurrences to illustrate and describe emergency service demands on a fire department. Areas are categorized into total number of incidents, total number of fire incidents, total number of EMS incidents, and total number of other miscellaneous emergency incidents. Relative measures utilize the collection of the above referenced data and place it into square mile grids. Valid comparisons on the different types of emergency services are made under this analysis.

While the form and manner of describing considerations for fire station site location may vary, the common thread among them include objective measurement or quantification, subjective analysis particular to the region, and cost.

In addressing the issue of impact on response it is important to understand why a fire department must be able to deliver resources within a determined time frame. Fires progress in a geometric fashion whereby an added increase in time of response results in fire damage growing in factors of multiplication (Petersen, 1998). This is due to the fact that as fire builds up it can go through different stages of development. This buildup can

be plotted on a timeline, the results of which are not linear, but logarithmic (Meyers, 1994).

The stage of fire buildup that is of critical concern with respect to service delivery is flashover. Flashover occurs when the fire gases and products of combustion that have accumulated during the first phases of burning simultaneously ignite. The flashover will generally spread the fire through out the structure and make the likelihood of saving life and property very doubtful (Meyers, 1994). This is due to flashover's sudden change from tenable atmosphere with good visibility and moderate heat to an atmosphere where death can occur within seconds (Petersen, 1998). The time that it takes to reach flashover is generally six to nine minutes (Gay & Siegel, 1987; McCarraher, 1992).

This data is important when calculating an appropriate response time standard for fire engines. Response time is actually a complex measurement of several identifiable time segments, namely, 1. The detection segment-defined as the time it takes between fire ignition and its detection; 2. The dispatch segment-defined as the time it takes from detection to notification and dispatch of emergency services; 3. The preparation segment-defined as the time it takes to mount the emergency apparatus and leave the station; 4. The travel time segment-defined as the time it takes to travel from the fire station to the emergency scene; and 5. The set up segment-defined as the time that is required to size up the situation, deploy hose lines, initiate search & rescue, etc. (McCarraher, 1992; Petersen, 1998).

Industry standards for response times range from four to six minutes. This is because it takes additional minutes to size up the situation, deploy hose lines, and initiate search and rescue (Petersen, 1998). A response time of four to six minutes is partially

derived from the intercession of flashover. The goal is to deploy operational mitigation measures before this event occurs (Meyers, 1994).

Coincidentally, emergency medical system (EMS) studies have indicated that patients who have suffered cardiac arrest, trauma, or stopped breathing must receive life sustaining treatment within four to six minutes to prevent permanent damage to the body system and brain damage (Meyers, 1994).

With respect to distance, the National Fire Protection Agency (NFPA) recommends the first due engine within 2 miles of residential, 1.5 miles within commercial areas and within 1 mile of buildings that require more than 5,000 gallons per minute fire flow (Gay & Siegel, 1987; Meyers, 1994).

The Insurance Services Office (ISO) recommends that the first due engine company should be located within 1.5 miles of major built up areas. It should be noted however, that many communities are creating more rational standards that are applied to meet their own specific needs (Requate, 1993).

Other considerations in addition to time and distance factors, include percent of developed area, daytime population versus nighttime population, square footage and value of the individual properties, conflagration potential, exposures, political pressures, topography, number of alarms, traffic, and special hazards such as interface (Sybesna, 1995). Traffic flow, construction costs, community input and financing are added to the assessment analysis when considering re-building or re-location (Edwards, 1992).

PROCEDURES

Definition of Terms

Advanced Life Support (ALS). A term associated with paramedic service.

Automatic Aid. An agreement made between adjacent fire jurisdictions whereby the closest fire units respond to an emergency without regard to jurisdictional boundaries.

Conflagration. This term is used to mean any large fire with significant flame spread from building to building or from forest or brush to buildings (NFPA,1997).

Emergency Medical Service (EMS). A term used in the emergency services profession pertaining to the treatment of patients with immediate or life threatening injuries or illnesses.

Fire Station Location and Mapping Environment (FLAME). FLAME is the trademark name associated with a computer software program utilized for fire station modeling and mapping (Bode Research Group, 1997).

Flashover. This term defines a transition phase of a fire that is characterized by instantaneous ignition of materials in all parts of the room. During flashover, the temperature rises very sharply to such a level that survival of the fire by persons still in the room becomes unlikely (NFPA, 1997).

Insurance Services Office (ISO). ISO is an independent statistical, rating and advisory organization that serves the insurance industry in helping to establish fire insurance premiums by rating fire protection services (Insurance Services Office).

National Fire Protection Association (NFPA). A nonprofit voluntary membership organization, founded in 1896, that is a clearinghouse for information on fire prevention, firefighting procedures, and methods of fire protection (NFPA, 1997).

Wildland Interface. A term common to the fire service defined as an area comprised of natural fuels found in a wildland setting that are adjacent to man-made fuels such as homes or other structures.

<u>Research Methodology</u>

The desired outcome of this research was to determine whether or not it was cost effective to re-locate and combine two existing fire stations without impacting service to the areas that each served. The research was historical through the literature review to the extent of understanding the relationship between fire station location and emergency fire response.

The research was action research in that the information gathered was applied in a real-world context. Response times and distance were selected criteria for this study. A computer modeling approach was chosen for statistical accuracy when tabulating travel times and distances within various geographic areas of the zones serviced by Fire Stations 43 and 16. This approach has been successfully applied in other jurisdictions and has gained wide acceptance as a tool for measuring response times, distance and identifying fire station location sites (Benton & Carpenter, 1987; Lewis, 1986; Meyers, 1994; Petersen, 1998).

The Fire Station Location and Mapping Environment (FLAME) computer software program was utilized to compute the best emergency travel routes between the two current fire stations and all street segments within the response zones. A third fire station, Fire Station 45, was factored into the model due to its proximity to station 43.

The FLAME program was set with parameters for first in fire engine response with travel time segments of up to 4 minutes (green), from 4 to 5 minutes (red) and 5 to 6 minutes (blue). Each of the three stations was independently measured to establish a baseline for maximum travel distance under the travel time segments. (See Appendix A.) A measurement was also taken based on the maximum travel time of 6 minutes. The

color red was utilized for station 45's response zone, green for station 43, and ocean blue for station 16. (See Appendix B.)

The three current Fire Stations 45, 43 and 16, were then simultaneously measured to determine the total number of miles that could be traveled under 4 minutes, between 4 to 5 minutes and between 5 to 6 minutes, with the same color graphics as above in Appendix A. (See Appendix C.) A measurement was also taken based on the maximum travel time of 6 minutes, and also calculating the closest responding fire station. (See Appendix D.) The same measurements including only station 43 and 16 were taken. (See Appendix E and F.)

Utilizing an actual driving survey of the roadway between station 43 and 16, unimproved lots of approximately ¾ to 1 acre in size were noted (two were found side by side) and then entered into the FLAME program. For study purposes this site location was named station 46.

An independent measurement was taken for station 46 as was done with the other three stations for the 4-5-6 minute travel mile response (See Appendix G), and the maximum travel time of 6 minutes. (See Appendix H, colored in light blue.)

Station 46 and station 45 were then simultaneously measured to determine the total miles of coverage under the 4-5-6 minute calculation and the total 6-minute response scenario. (See Appendix I and J respectively.)

The data collected from these studies was then utilized to compare service impact from the current station 45, 43 and 16 configuration with the station 45 and 46 configuration.

The graphics of the FLAME program was used to illustrate the measurable effect of these calculations.

A verification system was implemented to review actual time by driving selected routes at the speed limit, and marking the mid-point time of 5-minutes through out the zones under study. (See Table 1.) This study was utilized to verify response times in the FLAME computer-modeling program.

Assumptions and Limitations

This specific study and for that matter the premise for choosing a particular site for a fire station is based upon the assumption that the fire units will be dispatched from these fixed sites. It is also assumed that the fire units are equivalent in power and available in service to respond at all times. Fire units that are on district inspection, out of service on another emergency call or are of deficient power could affect actual response time (Mirchandani, P. B. & Reilly, J. M., 1985).

The importance of the impact of response time is actually a complex set of variables. In addition to travel time, the emphasis of this study, there are a number of other factors that can influence the overall response time. . Smoke detectors for example, can have a dramatic impact on response time by shortening the time it takes to detect and report a fire. With a smoke detector studies have shown that damage was limited to overheating and smoke, 94% of the time. When there was no smoke detector, open flames were generated 45% of the time, and in 60% of those cases there was significant fire spread. In those cases where there was a smoke detector and flame spread, the damage was limited to the area of origin 80% of the time (Gay & Siegel, 1987).

Dispatch and turnout time (the time required to leave a station) can also influence overall response time. (Gay & Siegel, 1987).   It was assumed that for the purposes of this study these factors would remain constant.

This study is limited to analysis of a first due engine responding within a geographic zone. It does not take into consideration multiple fire units responding for a fire nor for a second or third alarm assignment. This study is also limited in a lack of analysis regarding location of emergency incidents. A further study would be helpful in determining whether emergency incidents are concentrated to a particular area within a zone or are spread through out.

RESULTS

Verification of the FLAME computer program with actual time of travel was found to be 97% accurate. Six 5-minute real travel time trials were recorded then compared with the computer generated travel times and distances. The results of the verification study are recorded below in Table 1.

Table 1 Travel Time Verification

Street Name	Real Travel Time + or – to FLAME Time of 5 Minutes	Percent Accuracy
Upper Happy Valley	+ 10 seconds	97%
Tahos Road	0 seconds	100%
Altarinda	0 seconds	100%
Lombardi	+ 10 seconds	97%
St. Stephens	+ 10 seconds	97%
Bates	+ 10 seconds	97%

Table 2 represents the results of the independent time and travel distance studies

for Stations 43, 16, (proposed) 46, and combined 43 & 16. The results indicate that in

each of the three time and distance categories as well as the total distance category, the

Proposed Station 46 had more miles of coverage than Fire Stations 43 and 16

independently; and Fire Station 43 and 16 when placed in service simultaneously.

Table 2

Time and Travel Distance Measurements Sta. 43, 16, 46, 43/16

Fire Station	Total miles within 0-4 Minutes	Total miles from 4-5 Minutes	Total miles from 5-6 Minutes	Total miles within 6 Minutes
Station 43 Appendix A & B	44.2 total miles	25.1 total miles	45.3 total miles	114.6 total miles
Station 16 Appendix A & B	27.7 total miles	25.9 total miles	47.3 total miles	100.9 total miles
Stations 43 and 16 Appendix E & F	64.6 total miles	32.6 total miles	48 total miles	145.2 total miles
Proposed Station 46 Appendix G & H	64.8 total miles	38.2 total miles	54.2 total miles	157.2 total miles

Further time and distance measurements were done to compare the current

Stations 45, 43 and 16 site configuration with the proposed combined and relocated

Station 46 placed in service with Station 45. The results indicate an increase in total
distance of service coverage in each of the three time and distance categories and for total
miles covered. The results are shown in Table 3 below. The combining of Fire Stations
43 and 16 and relocating to a different site location within the FLAME program did result
in faster response times in relation to the distance traveled.

Table 3

Time and Travel Distance Measurements of Current Sta. 43, 16 & 45

And Proposed Sta. 46 &45

Fire Station	Total miles within 0-4 Minutes	Total miles from 4-5 Minutes	Total miles from 5-6 Minutes	Total miles within 6 Minutes
Station 43, 16 & 45 Appendix C & D	79.2 total miles	32.5 total miles	44.6 total miles	156.3 total miles
Station 46 & 45 Appendix I & J	86.9 total miles	43.9 total miles	51.9 total miles	182.7 total miles

DISCUSSION

In comparing the historical data with the current siting of the five fire stations
located in the MOFD and the three fire stations located in Lafayette belonging to Con
Fire, there appears to be a logical relationship with respect to distance. Historically, the
industry standards recommended a maximum travel distance of 1.5 to 2 miles for the
response of a first due Engine Company to an emergency (Gay & Siegel, 1987; Meyers,
1994; Requate, 1993). Given this maximum travel distance then one can mathematically
conclude that no two adjacent fire stations should be more than 3 to 4 miles apart. Each

of the fire stations were found to be sited approximately 3 miles apart, give or take 1 to 2

tenths of a mile.

The one exception to this standard was found with the relationship between Fire

Station 43 and Fire Station 16. There the distance was found to be 1.6 miles. Upon

further observation it is noted that these fire stations are located in hilly terrain and are

further separated by a canyon that coincidentally serves as the jurisdictional line between

the City of Orinda and the City of Lafayette. Negative factors in considering siting of

fire stations include hilly or mountainous areas and natural barriers such as canyons

(McCarraher, 1992). Political considerations are another criteria that can enter into the

decision making process for fire station site location (Meyers, 1994), however, it is

undetermined whether this may have been a contributing factor with respect to station 43

and 16. The other station located in Lafayette (Station 17) is approximately 3 miles from

the nearest station located in Moraga (Station 42) but does not have the same terrain or

natural barriers that are present with station 43 and 16.

Regardless of the considerations that initially went into the construction of these

two fire stations, it is clear from the data that neither is located at an optimum site. The

proposed Fire Station 46 is within 3 miles of the closest fire station in Orinda (Station 45)

and the closest fire station in Lafayette (Station 15). Placing the proposed fire station at

the foot of the hill eliminates the problem with the canyon and provides easier access into

the hill area.

Research of the literature reveled that response time standards ranged from 4 to 6

minutes (Meyers, 1994; Petersen, 1998; Sybesna, 1995). A response time standard of 4

to 6 minutes was utilized when conducting the time travel distance studies with the

FLAME computer-modeling program.

The results of the computer program modeling indicated that relocating and consolidating Fire Station 43 and Fire Station 16 improved overall emergency response to the community. The proposed Fire Station 46 can respond to 64.8 miles in less than 4 minutes, 38.2 miles between 4 to 5 minutes and 54.2 miles between 5 to 6 minutes for a total of 157.2 miles. (See Appendix G and Table 2.) This is greater than Fire Station 43 with 44.2, 25.1, 45.3 miles respectively and a total of 114.6; or with Fire Station 16 with 27.7, 25.9, 47.3 and 100.9. (See Appendix A and Table 2.)

When the proposed Fire Station 46 was placed in service in conjunction with Fire Station 45, it was found that a greater amount of response coverage was available than with the current combined station coverage provided by Fire Station 45, 43 and 16. The 45/46 model provided 86.9 miles less than 4 minutes compared with 79.2 miles in the 45/43/16 model. The 4 to 5 minute response range resulted in 43.9 and 32.5 respectively; and the 5 to 6 minute range was 51.9 and 44.6. The total miles covered by the 45/46 model that were under 6 minutes were 182.7. This was greater than the total miles of 156.3 provided by the 45/43/16 scenario. (See Appendix C, I and Table 3.)

The major factor that resulted in the improved coverage was the strategic location of the proposed Fire Station 46 along El Nido Road. El Nido Road runs as a frontage along the base of the hillside. Entry into most of the streets serviced in both station 43 and 16's area can be made from El Nido Road. The canyon that runs as a natural barrier between Fire Station 43 and 16 ends at El Nido Road and does not affect emergency response.

The computer modeling provided with the FLAME program was verified with real time analysis. The verification found the FLAME program to be 97% accurate. (See Table 1.)

RECOMMENDATION

Taxpayer moneys could be more effectively utilized through the combining of Fire Station 43 and Fire Station 16 and relocating to a new strategic site. The data supports this conclusion with the proposed new site, in place of the two existing stations, by increasing total miles of emergency coverage within the same timeframes.

The proposed new site would be within 3 miles of the closest fire stations maintaining the consistency of a maximum 1.5-mile response according to recommended standards.

The data supports the conclusion for a yearly savings of $520,000 each for the MOFD and Con Fire due to the efficiency of one fire station and one engine company that is strategically located, compared to two fire stations and two engine companies that are not strategically sited.

Each fire district could save an additional $1,000,000 each in capital costs by sharing the expense of constructing one new fire station instead of two.

It is recommended that the MOFD and Con Fire continue with a joint partnership in addressing some of the other factors regarding this proposal. Due to the topography of the hills and local weather conditions there is a potential for a wildland interface conflagration. Special hazards such as wildland interface need to be explored to determine the potential impact of this proposal.

An analysis of the increased volume of emergency calls, while appearing to remain minimal (30-36 per month), needs confirmation through further research to determine the potential for simultaneous calls to the area. If simultaneous calls occur an engine from another response zone will be required to cover in. The question that needs to be answered is how often is this likely to occur? Analysis of response records will provide the risk potential of this type of event.

Community input, support and education will be crucial to the success of this proposal since they are the key stakeholders whose benefit the emergency service is designed to provide. The recommended approach is to hold public meetings and present the information and data, and answer any questions or concerns that they may have.

The concerns of personnel should also be addressed. Firefighter safety is of utmost importance and it is critical that this will not be compromised. An analysis of the potential impact should be done including what mitigation measures could be implemented regarding any concern. Questions with respect to surplus personnel will need to be addressed as well. It is recommended that provision for absorption through attrition be made so that the potential impact on job security is eliminated.

Given that these organizational and community concerns are addressed, it would be rational and logical to proceed with the construction of a single fire station along El Nido Road in replacement of Fire Station 43 in the MOFD and Fire Station 16 in Con Fire.

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